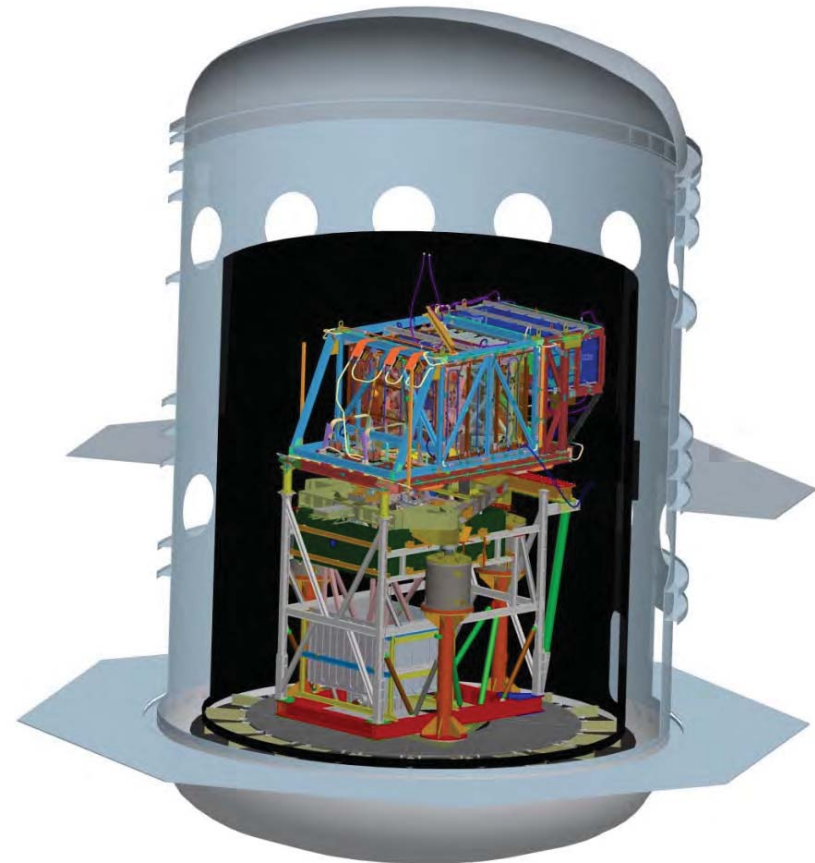


James Webb Space Telescope (JWST) Integrated Science Instruments Module (ISIM) Cryo-Vacuum (CV) Testing at GSFC

Calinda Yew
28th Space Simulation Conference
NASA Goddard Space Flight Center
(GSFC)



Topics

- JWST Mission Overview
- ISIM CV Test Campaign at GSFC
- Test Configuration
- CV1 Test Summary
- CV1 Chamber Performance
- Improvements in Path Forward to CV2 & CV3
- Summary



JWST Mission Overview

Mission Objective

- Study the origin and evolution of galaxies, stars & planetary systems: *Optimized for infrared observations (0.6 – 28 μm)*

Organization

- Mission Lead: Goddard Space Flight Center
- International collaboration with ESA & CSA
- Prime Contractor: Northrop Grumman Space Technology
- Instruments:



– Near Infrared Camera (NIRCam) – Univ. of AZ



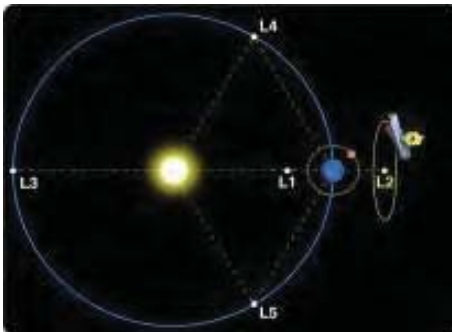
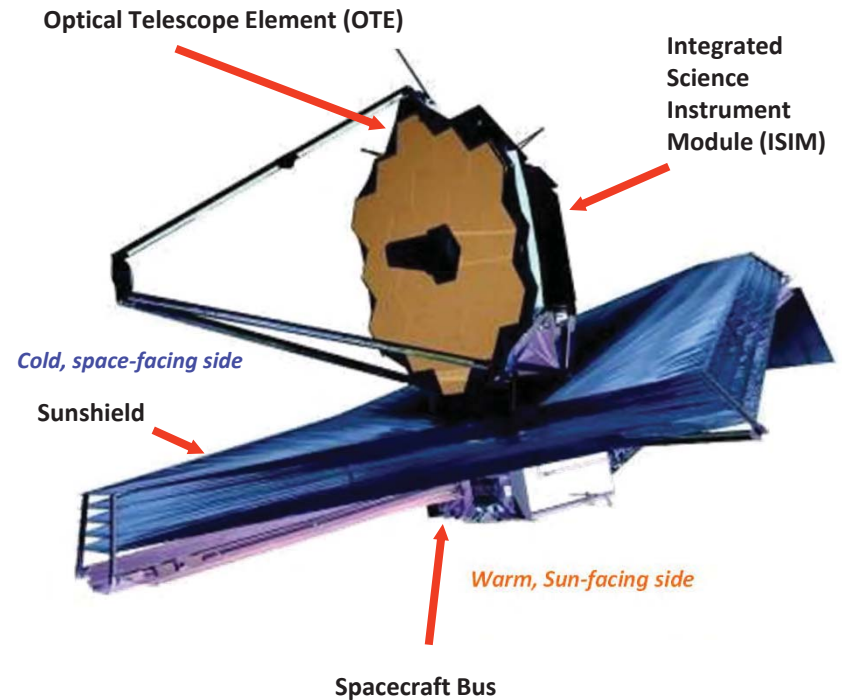
– Near Infrared Spectrograph (NIRSpec) – ESA



– Mid-Infrared Instrument (MIRI) – JPL/ESA



– Fine Guidance Sensor (FGS) – CSA

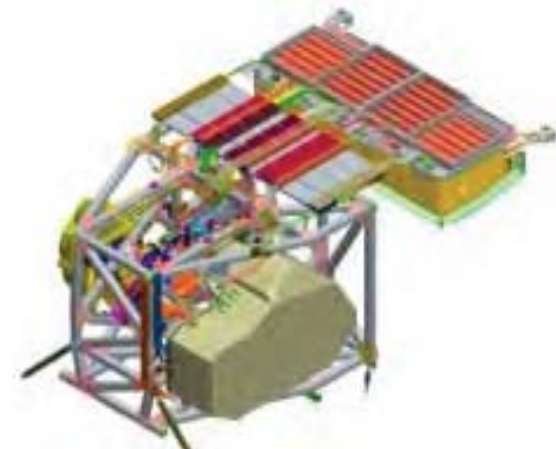
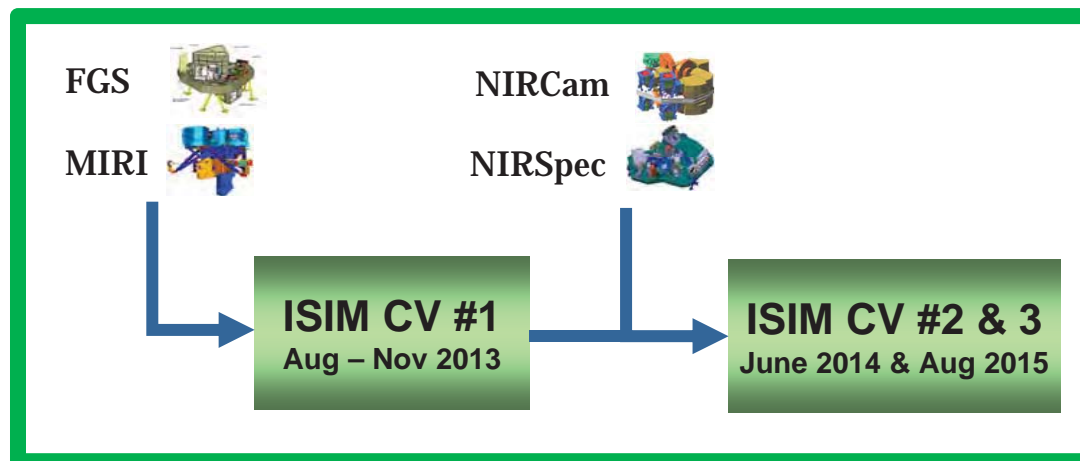


Description

- Deployable telescope w/ 6.5m dia segmented adjustable primary mirror
- Cryogenic temperature telescope and instruments for infrared performance
- Launch Oct 2018 on ESA-supplied Ariane 5 ECA rocket to Sun-Earth L2
- 5-year science mission + 2 years of data analysis



ISIM CV Test Campaign at GSFC



ISIM CV Overall Test Configuration



Chamber specifications
 Volume: 27' dia x 40' high
 Pumping speed

- 7 cryopumps: 2.1×10^5 l/s
- Turbomolecular pump: 6,000 l/s

Payload support: 40,000 lbs

Nitrogen shroud

Helium shroud

ISIM hardware & support frames

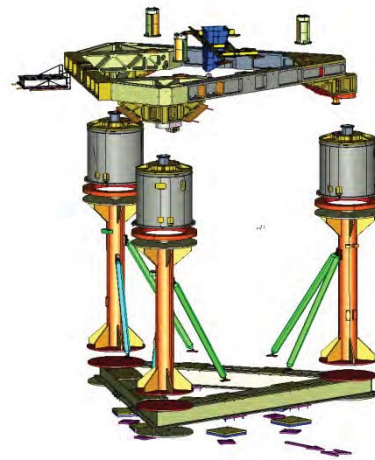
JWST OTE Simulator (OSIM)

Vibration isolators

Upper and Lower Supports Assembly



Nitrogen Volume Test Configuration



N₂ Volume Support Hardware Components

GSFC Equipment Support Hardware Assembly (GESHA): triangular Al structure to alleviate motion between two aligned systems

- Upper GESHA held at around 90K (-183°C)
- Lower GESHA: held at ambient temperatures to alleviate CTE induced strains

Vibration Isolators System (VIS): pneumatic system isolates test articles from chamber induced jitter sources

- Chamber vibration measured amplitudes of 1 milli-G in all axes at 20 Hz – VIS provides minimum attenuation of 40 dB to these levels
- VIS vertical natural frequency is 1.0-1.3 Hz
- VIS horizontal natural frequency is 0.4-0.6 Hz

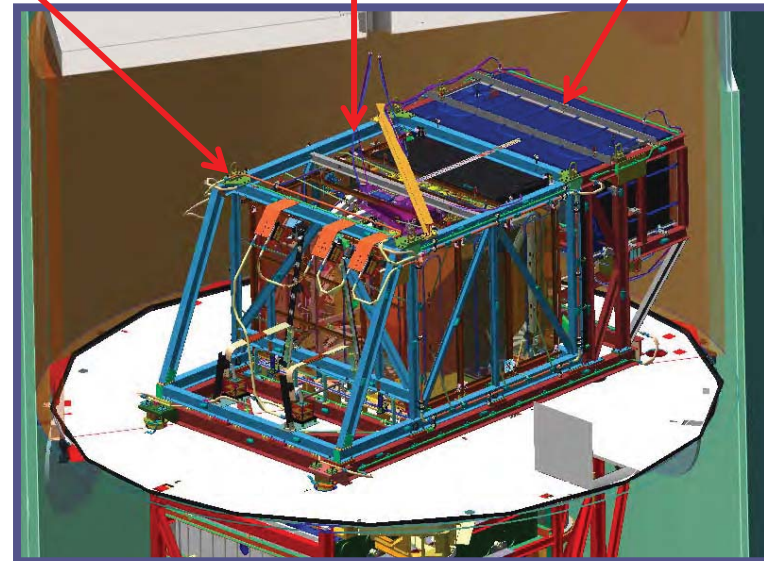
Helium Volume Test Configuration



*SIF & STMS
Frame*

*HR Shroud
(HR)*

*IEC Shroud
(IEC LN₂ Panel)*



*SIF = SES Integration Frame
STMS = Surrogate Thermal Management System
IEC = Instruments Electronics Module*

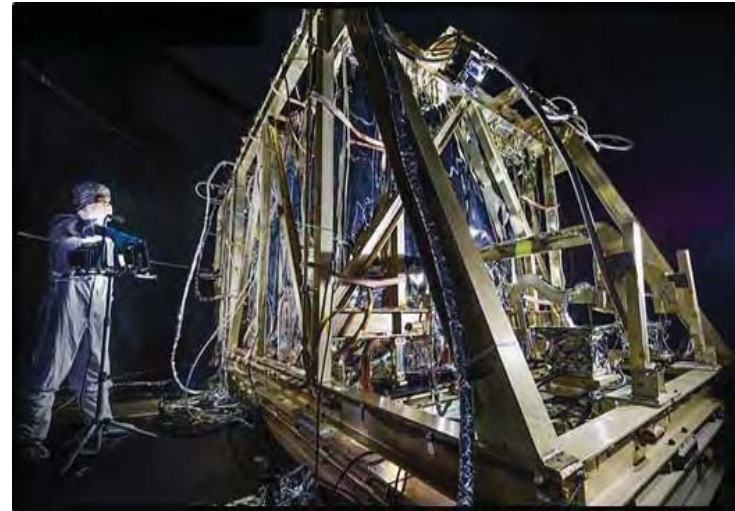
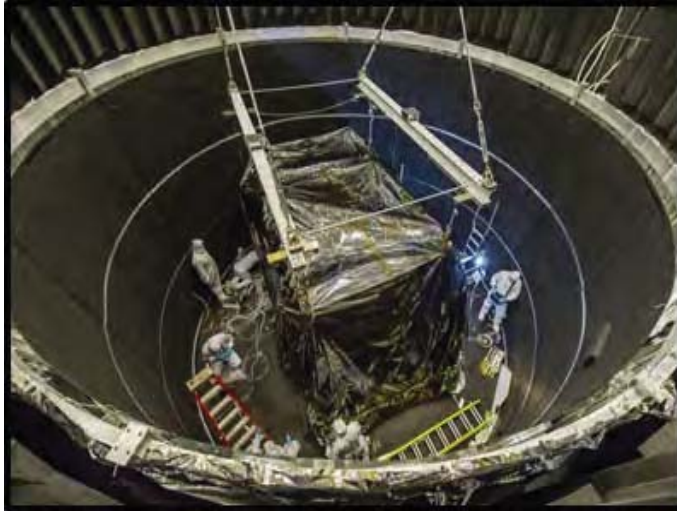
*HR = Harness Radiator
DSR = Deep Space Radiator*

He Shroud Specifications

- Dimensions 26' dia x 15' tall
- Provide 1000 W cooling capacity
- Cooling between 80K (-193°C) and 20K (-253°C)
- Five independently controlled shroud zones
- The other five helium zones are allocated to various parts of ISIM structure



ISIM CV1 Test Summary



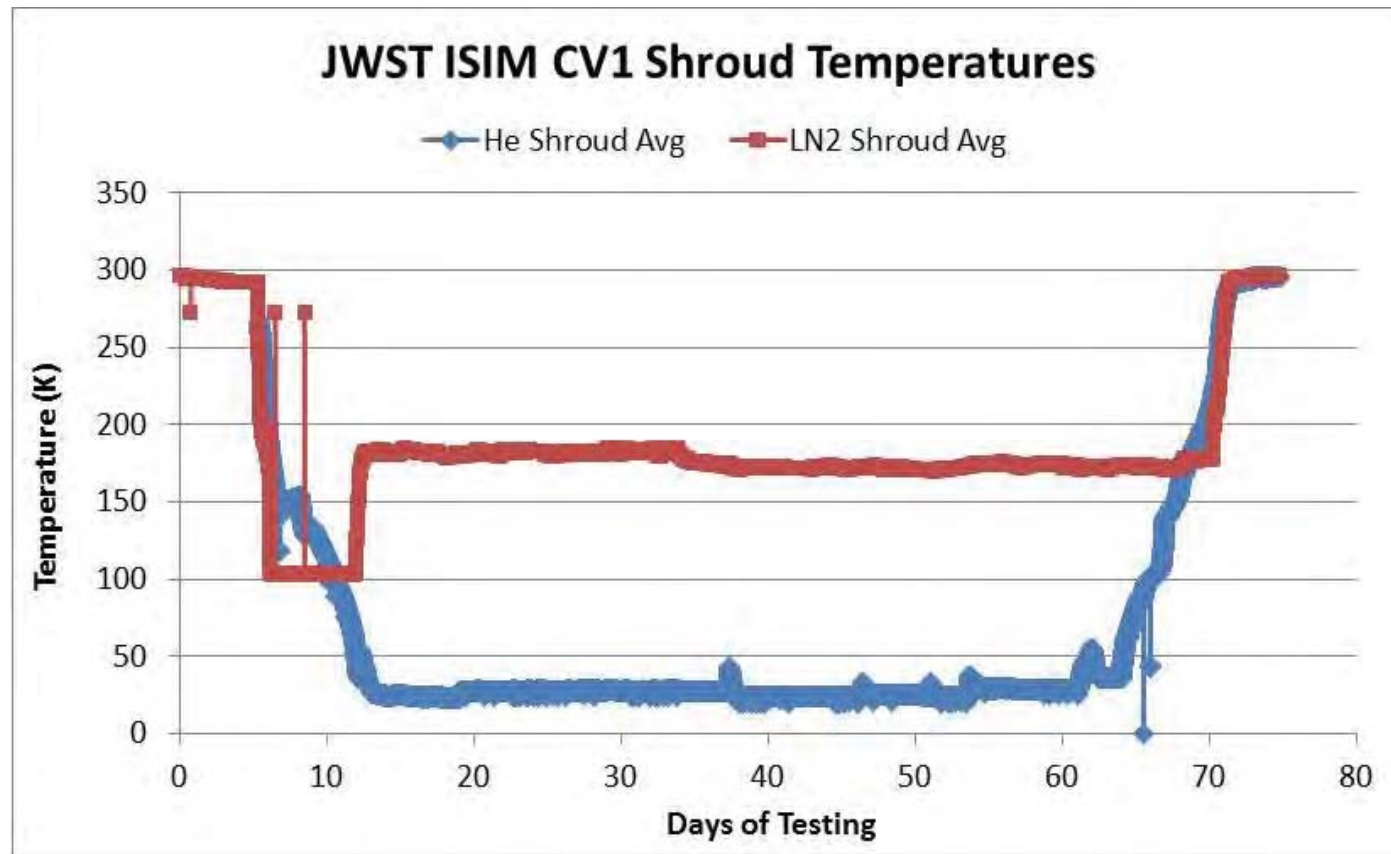
- Pump-down: 08/29/2013 ~21:00
- Warm-up: 10/29/2013
- Open chamber: 11/11/13
- Total days under vacuum = 73 days
- Total consumables
 - LN_2 = 520K gallons
 - Helium = 20 bottles



Shrouds Temperature Performance

At steady state: Helium shroud achieved $24\text{K} \pm 1\text{K}$

LN2 shroud maintained $182\text{K} \pm 3\text{K}$ (switched LN2 to GN2 Day 11: 9/10/13)



Chamber Vacuum Performance

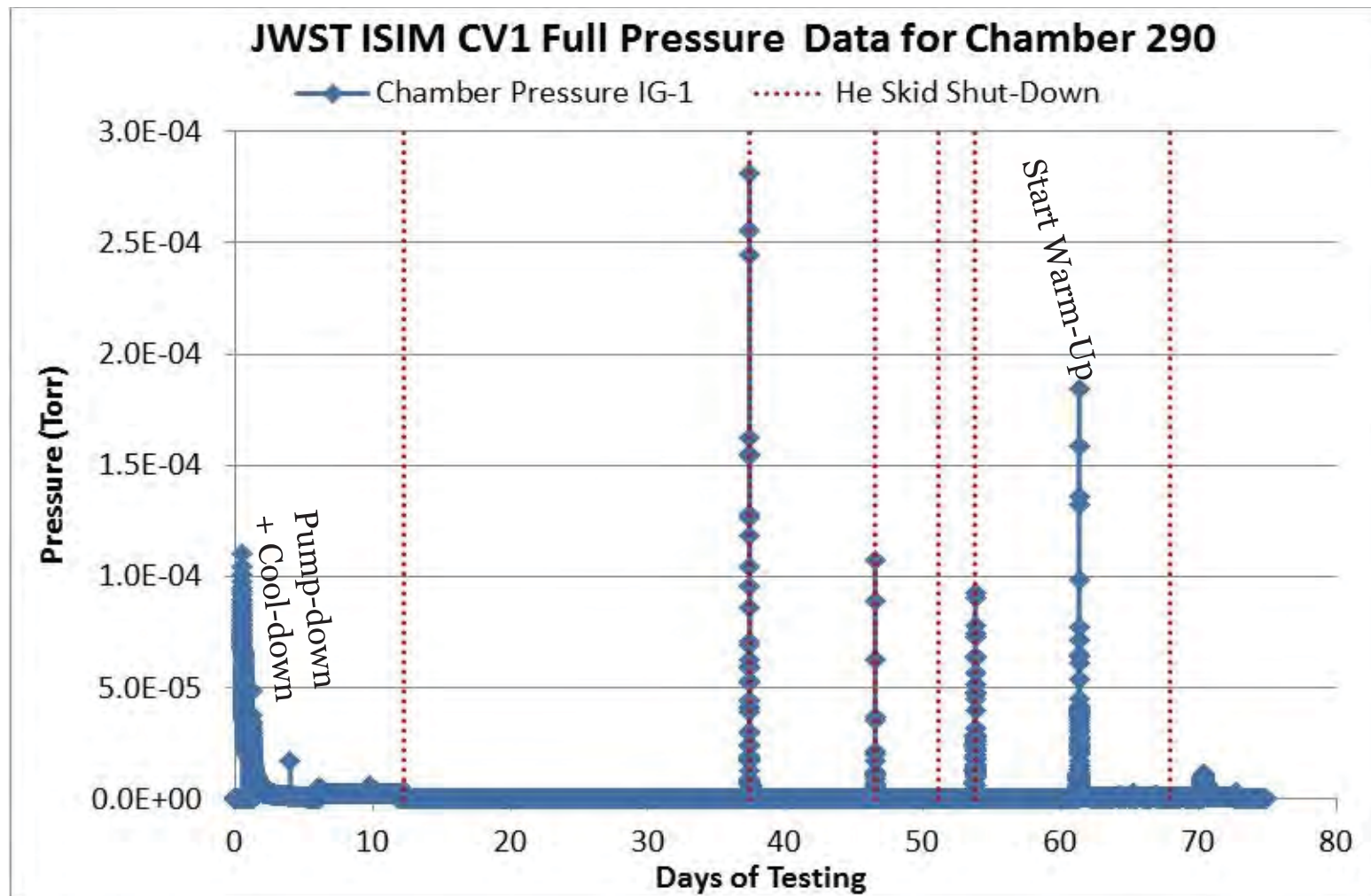
- High vacuum was achieved using:
 - (qty 6) 65000 liter/sec cryopumps
 - (qty 1) 5000 liter/sec turbopump
- 1 (of 6) cryopumps left in reserve at all times

Pressure (Torr)	Time since start
5.0 x 10 ⁻⁵	29 hrs (1.2 days)
1.0 x 10 ⁻⁵	35 hrs (1.5 days)
5.0 x 10 ⁻⁶	46 hrs (1.9 days)
1.0 x 10 ⁻⁶	108 hrs (4.5 days)
5.0 x 10 ⁻⁷	128 hrs (5.3 days)



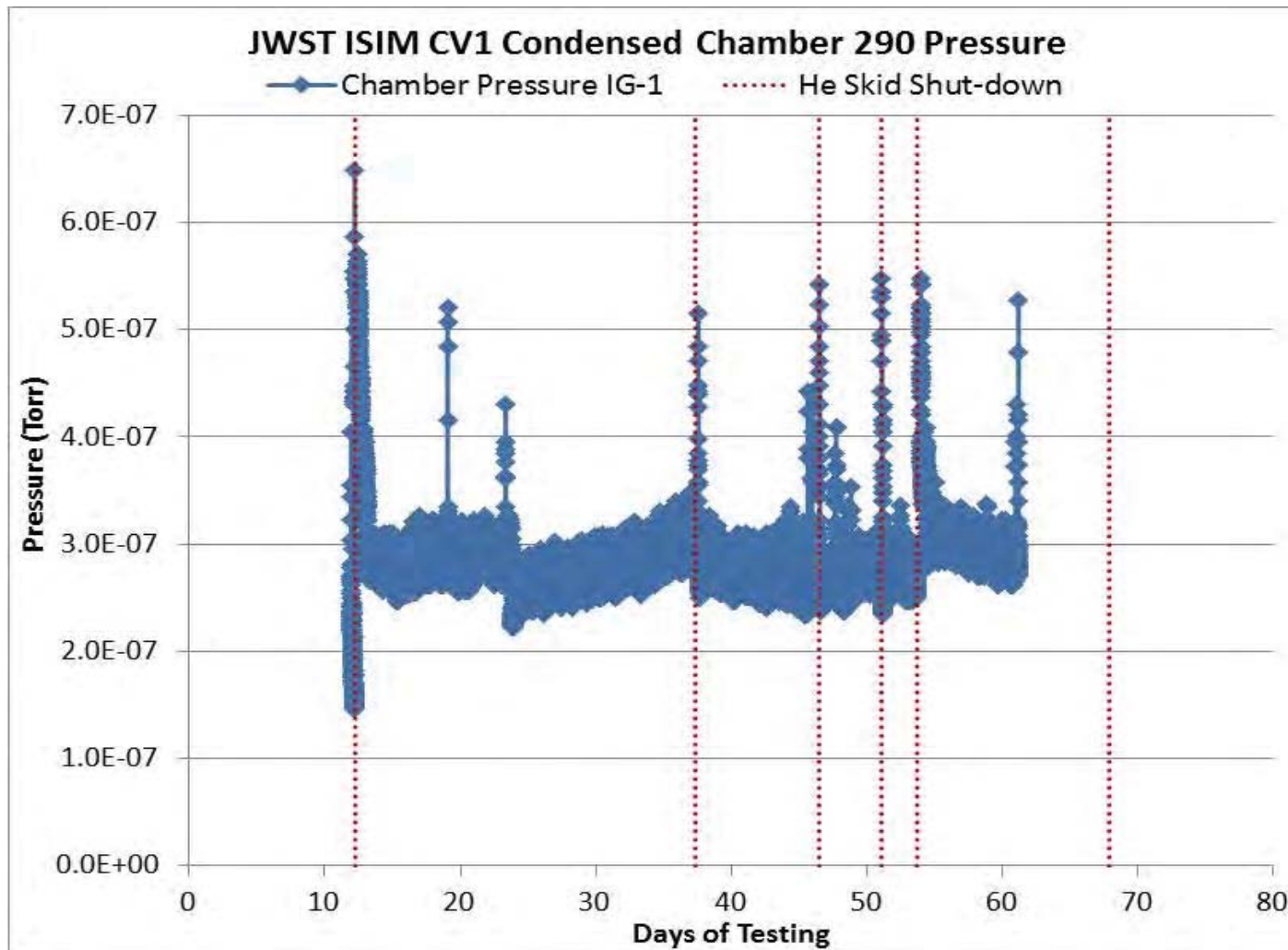
Chamber Vacuum Performance

Chamber pressure from pump-down to back-fill



Chamber Vacuum Performance

With cool-down, warm-up, & He skid shut-down pressure spikes omitted, normally 3×10^{-7} Torr



Improvements for CV2 & CV3

- Helium skid reliability needed to be improved in order to reduce risk to flight hardware and to schedule
- Detection of helium leaks needed to be more stringent in order to verify MIRI head loads



Helium Skid Reliability: Summary of Helium Skid Shutdowns

Total of six (6) helium skid shutdowns:

- Cause #1: low turbine bearing gas temperature alarm
- Cause #2: compressor oil level/temp alarm

#	Date	Cause	Action (back online)	Pressure Spike	Duration*	He Temp (Temp rise)	Duration**
1	09/10/13	#1	Re-start skid (<1 hr)	4.1×10^{-6} Torr	4.0 hrs	52K (+16K)	11.2 hrs
2	10/05/13	#1	Re-start skid (<1 hr)	2.8×10^{-4} Torr	5.3 hrs	42K (+15K)	8.5 hrs
3	10/15/13	#2	Re-start skid (<0.5 hr)	1.1×10^{-4} Torr	1.1 hrs	33K (+9K)	14.0 hrs
4	10/19/13	#2	5-sec interlock to delay shutdown command	9.3×10^{-5} Torr	1.1 hrs	32K (+8K)	6.5 hrs
5	10/22/13	#2	Override compressor load/unload status	9.2×10^{-5} Torr	6.1 hrs	37K (+13K)	N/A
6	11/05/13	#2	Re-start skid (~1 hr)	6.8×10^{-6} Torr	2.1 hrs	N/A (warm-up)	N/A (warm-up)

*Duration for pressure to return to 5×10^{-7} Torr

**Duration for helium shroud average temperature to return to temp before shut-down



Replace Dunham Busch Compressor
6 to 10 week delivery
Successfully installed & checked out May 2014

Old

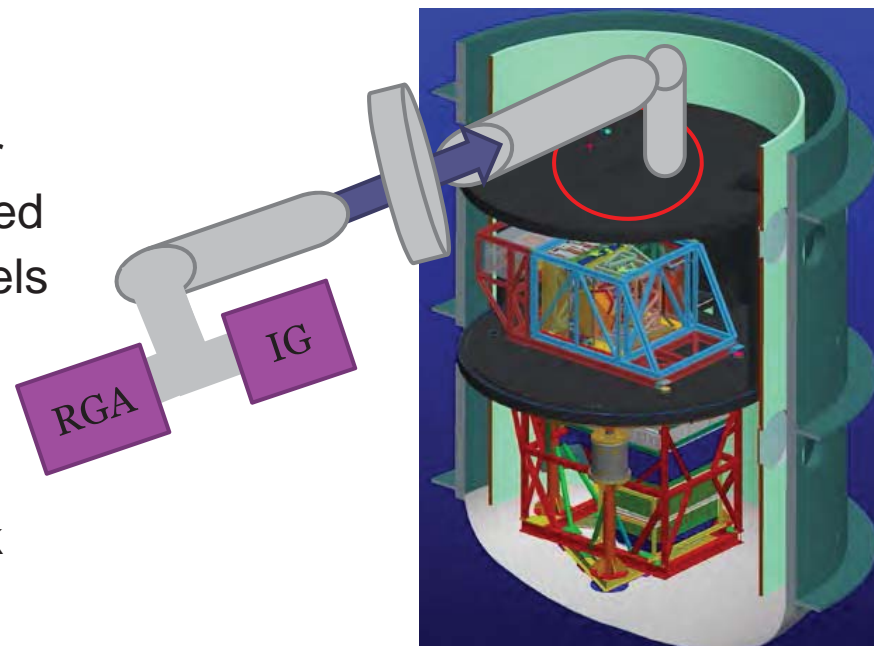


New



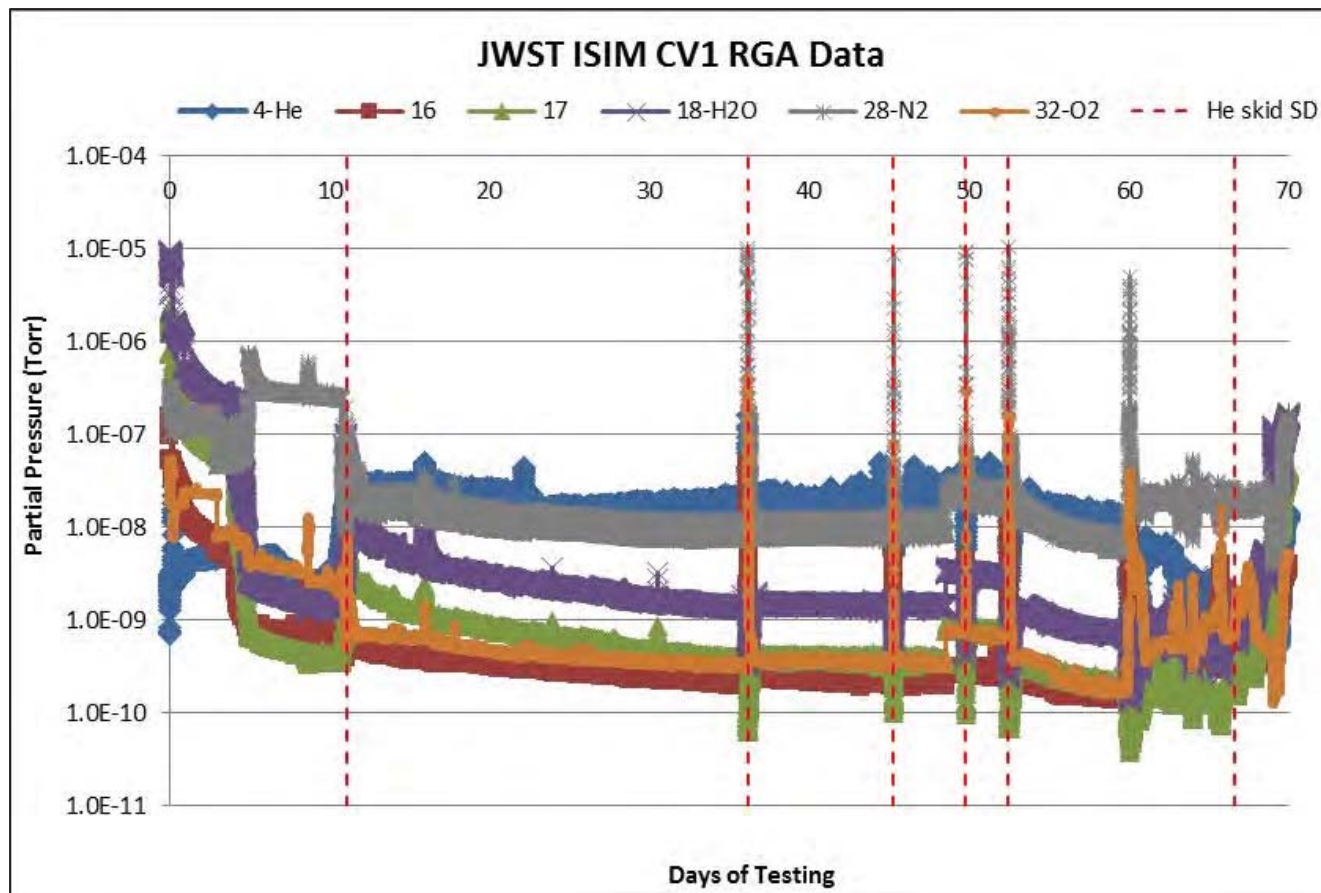
Helium Leak Detection Improvement

- MIRI requirement: 6.2 K (-266.8°C) at the instrument
 - 2-stage cooler system
 - Accurate heat map required during environmental testing
- Issues encountered during CV1
 - Measured heat loads to cooler from MIRI higher than expected
 - Presumed cause is higher levels of helium in chamber
- Actions
 - Add RGA in STMS volume a
 - Implement more stringent leak checking requirements

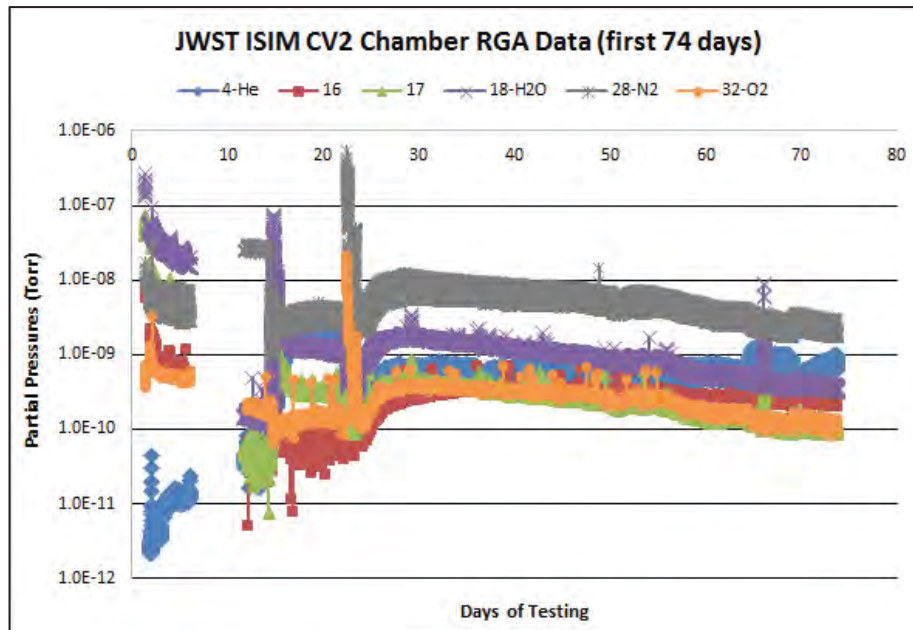


JWST ISIM CV1 RGA Data

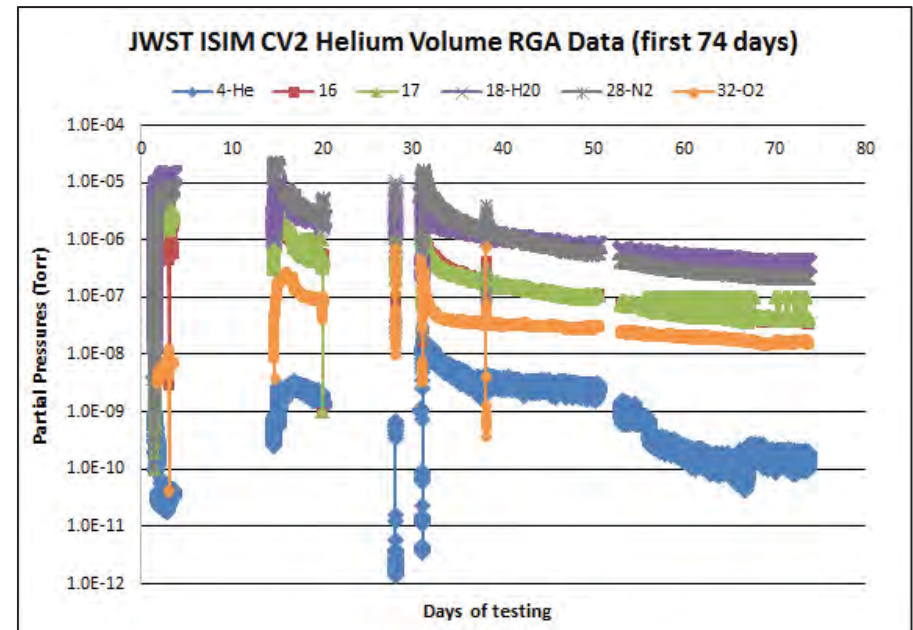
The chamber RGA detected helium levels of 5.0×10^{-7} Torr



JWST ISIM CV2 RGA Data Preview



Helium levels consistently detectable to levels of 1.0×10^{-9} Torr (as opposed to 5.0×10^{-7} in CV1)



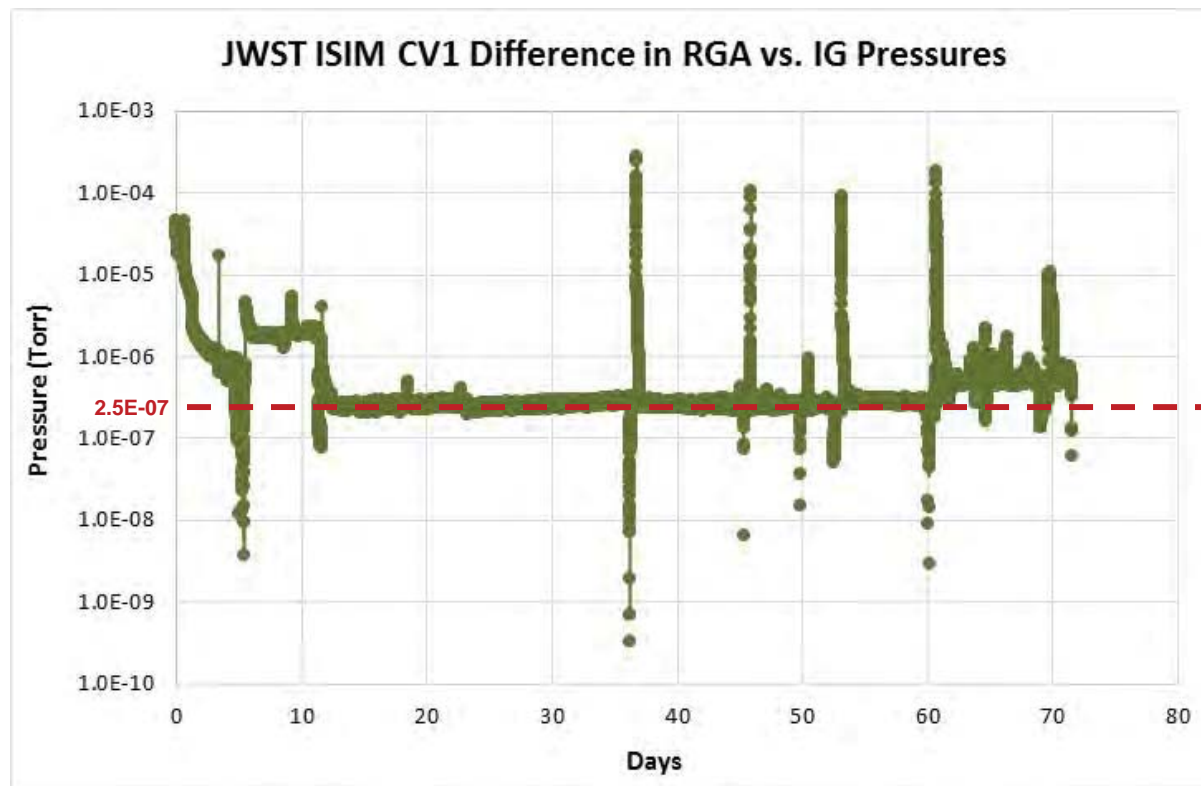
Helium levels in ISIM volume slightly higher than in the N₂ chamber volume: consistently $< 1.0 \times 10^{-8}$ Torr

The MIRI predicted thermal loads matched the measured within the prediction and measurement uncertainties



JWST ISIM RGA Data Reliability

- The need for a calibrated RGA is being investigated for CV3 testing as the total RGA pressure does not match the chamber ion gauge pressure readings: chamber RGA was $\sim 2.5 \times 10^{-7}$ Torr higher
- Currently, qualitative statements can only be made using the RGA data



Summary

- Successful CV1 test
 - Dry run of test procedures and processes
 - Achieved thermal requirements
 - Identified facility performance improvements necessary
- Two notable facility improvements
 - New helium skid compressor
 - Additional helium shroud RGA
- Future investigation into improving confidence in RGA readings



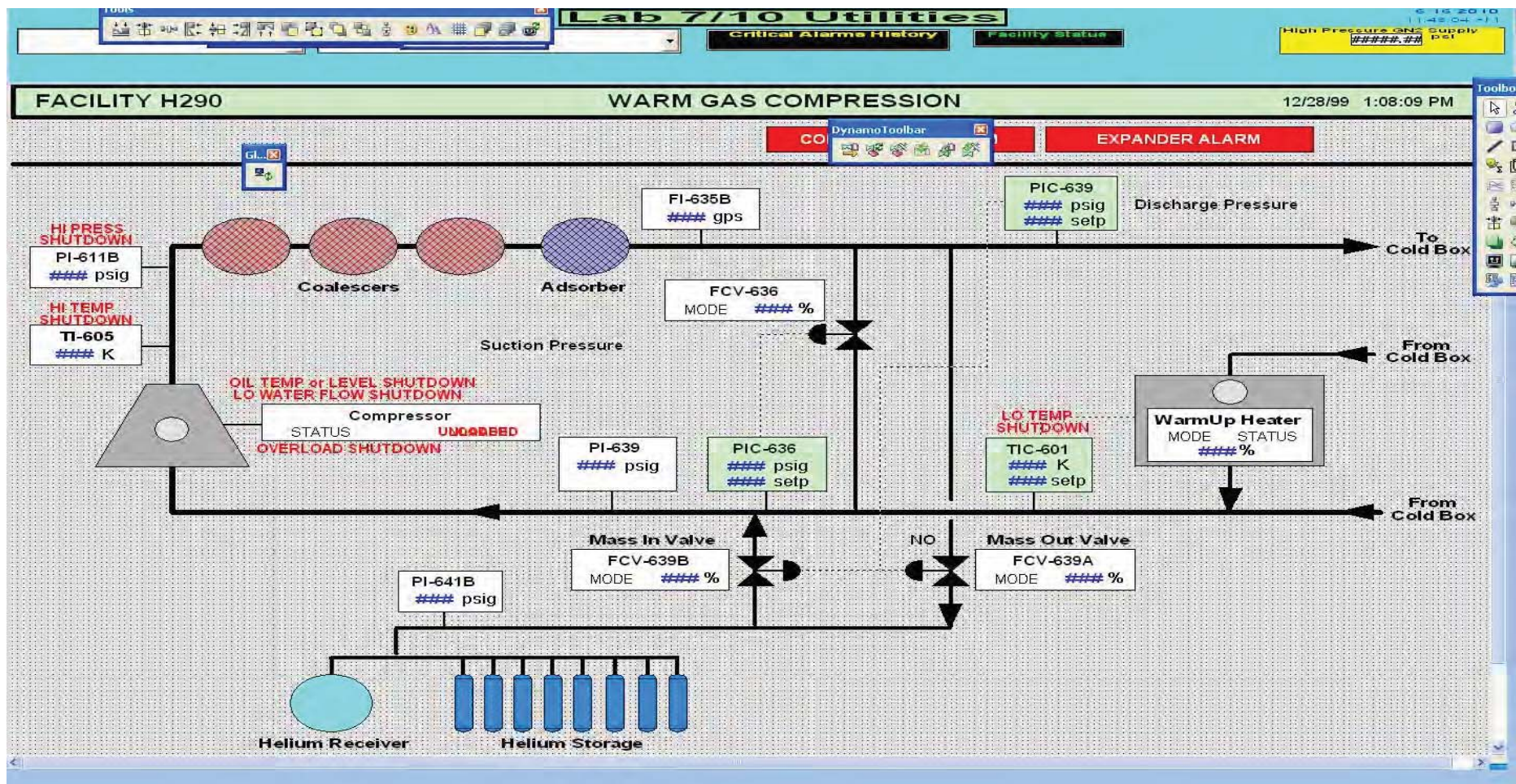
Questions?



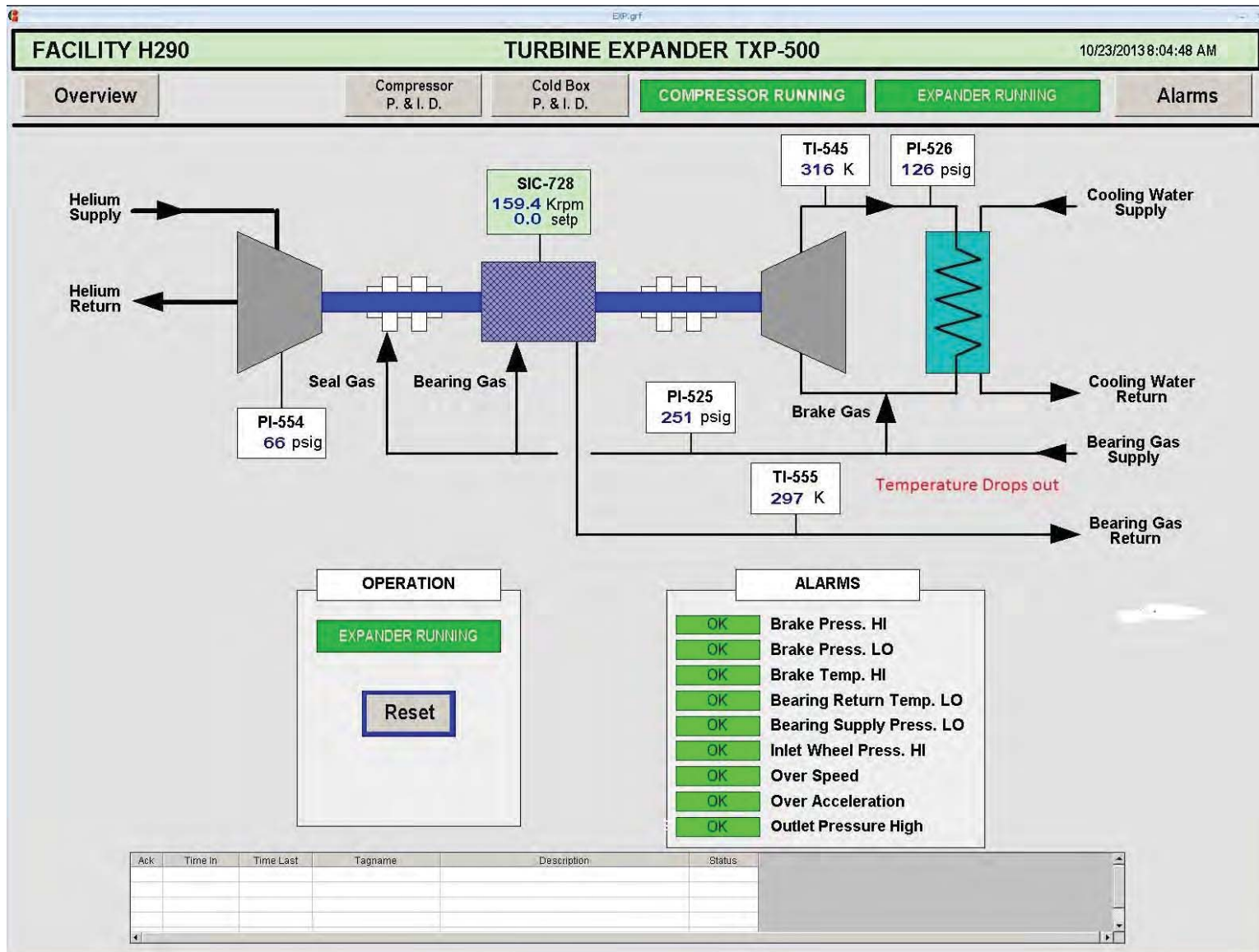
Back-Up Slides



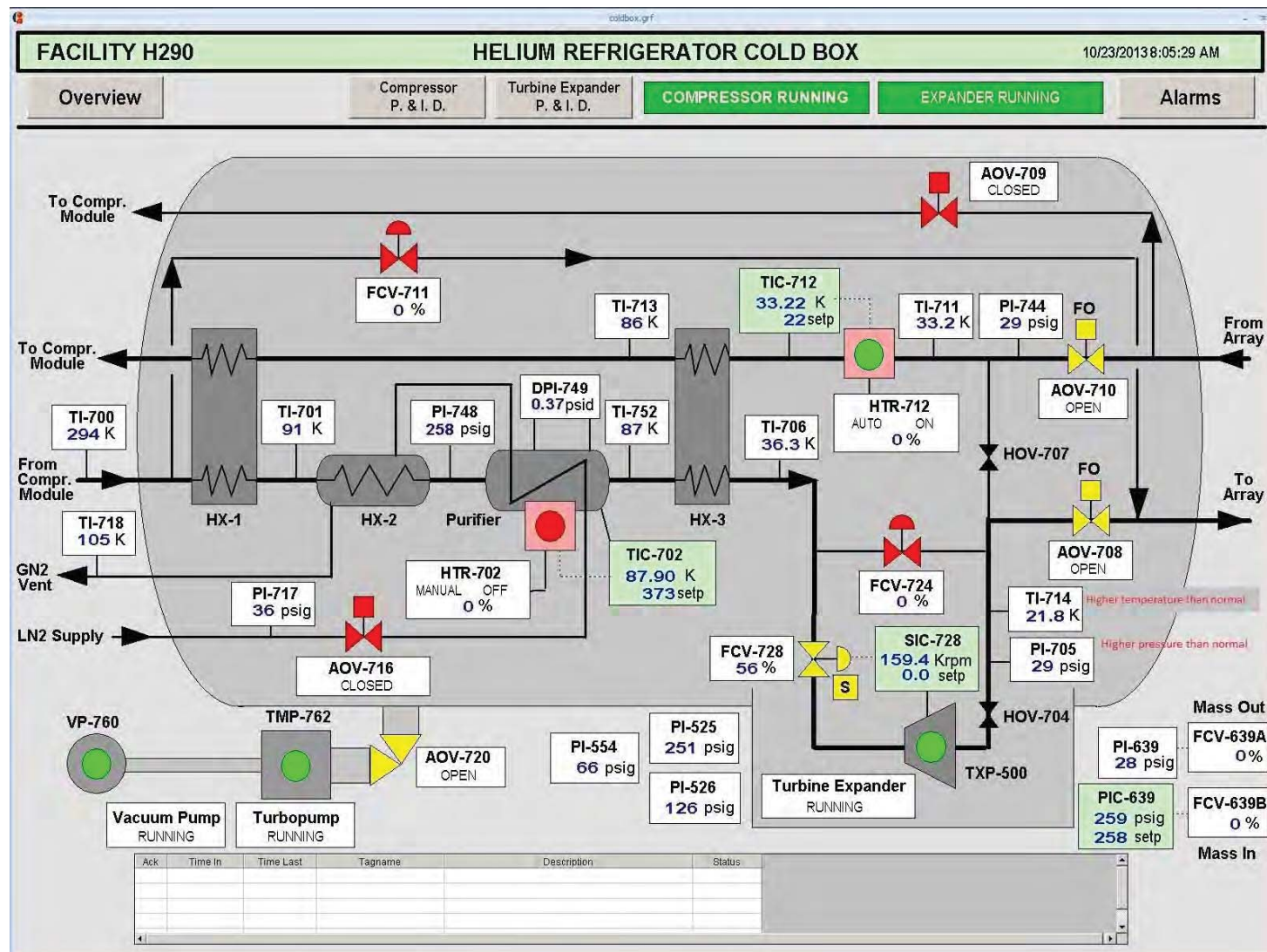
Helium Skid Shutdown Cause #1: Low & high oil temperature interlocks (false readings)



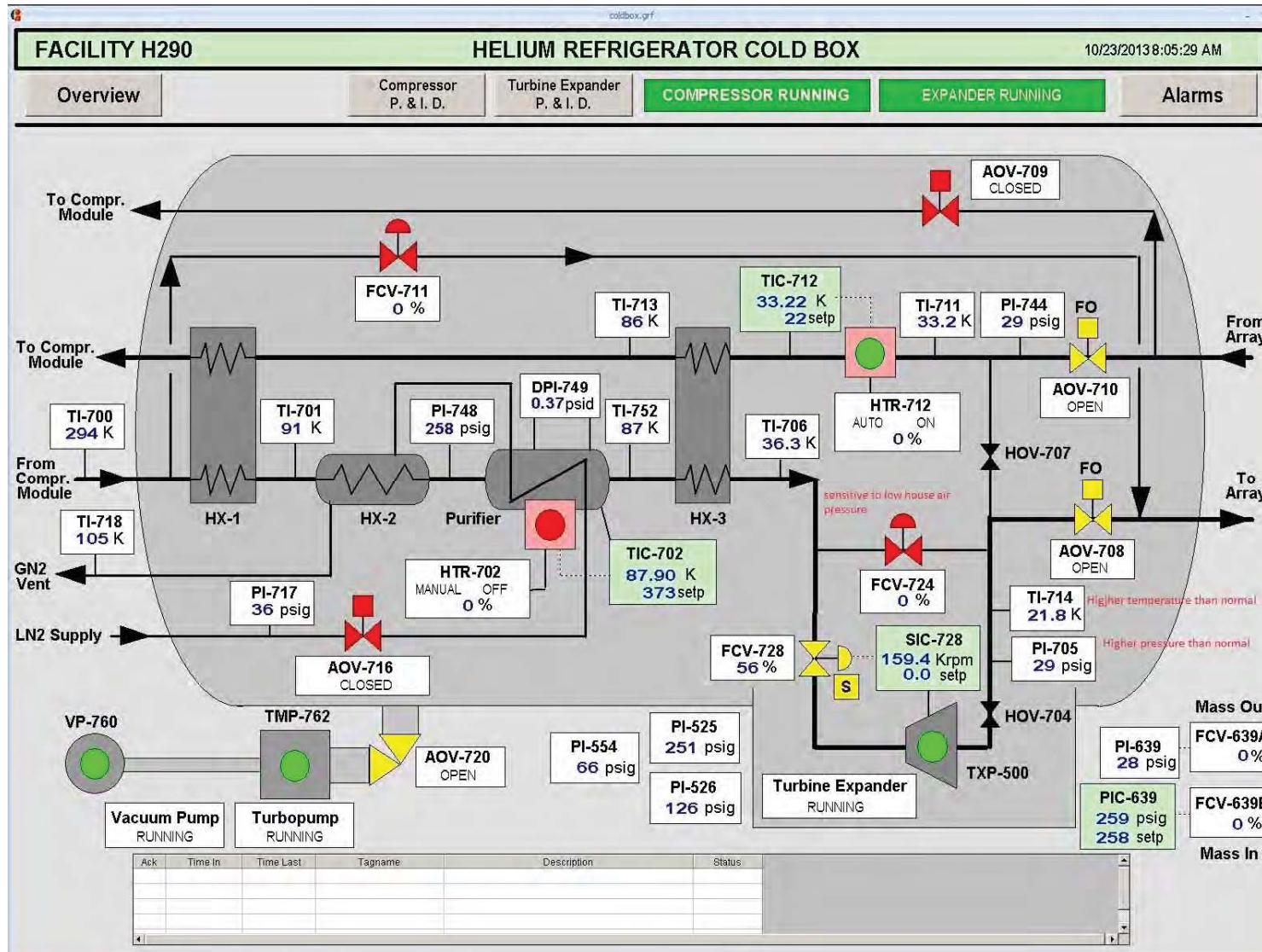
Helium Skid Shutdown Cause #2: Low turbine bearing return temperatures



Helium Skid Issues #3: Unable to achieve 20K on refrigerator due to compressor loading mechanism malfunction



Helium Skid Issues #4: In-house air pressure fluctuations House air pressure drops cause helium skid to warm up



Power Supply Operation

- All heater racks functioned as required for entire test duration
 - 9 heater racks
 - 14 LS-336s
- Only issue: heater circuit 8-2
 - Control sensors failed
 - Placed in local mode during the test
 - Resolution: Fix broken wire

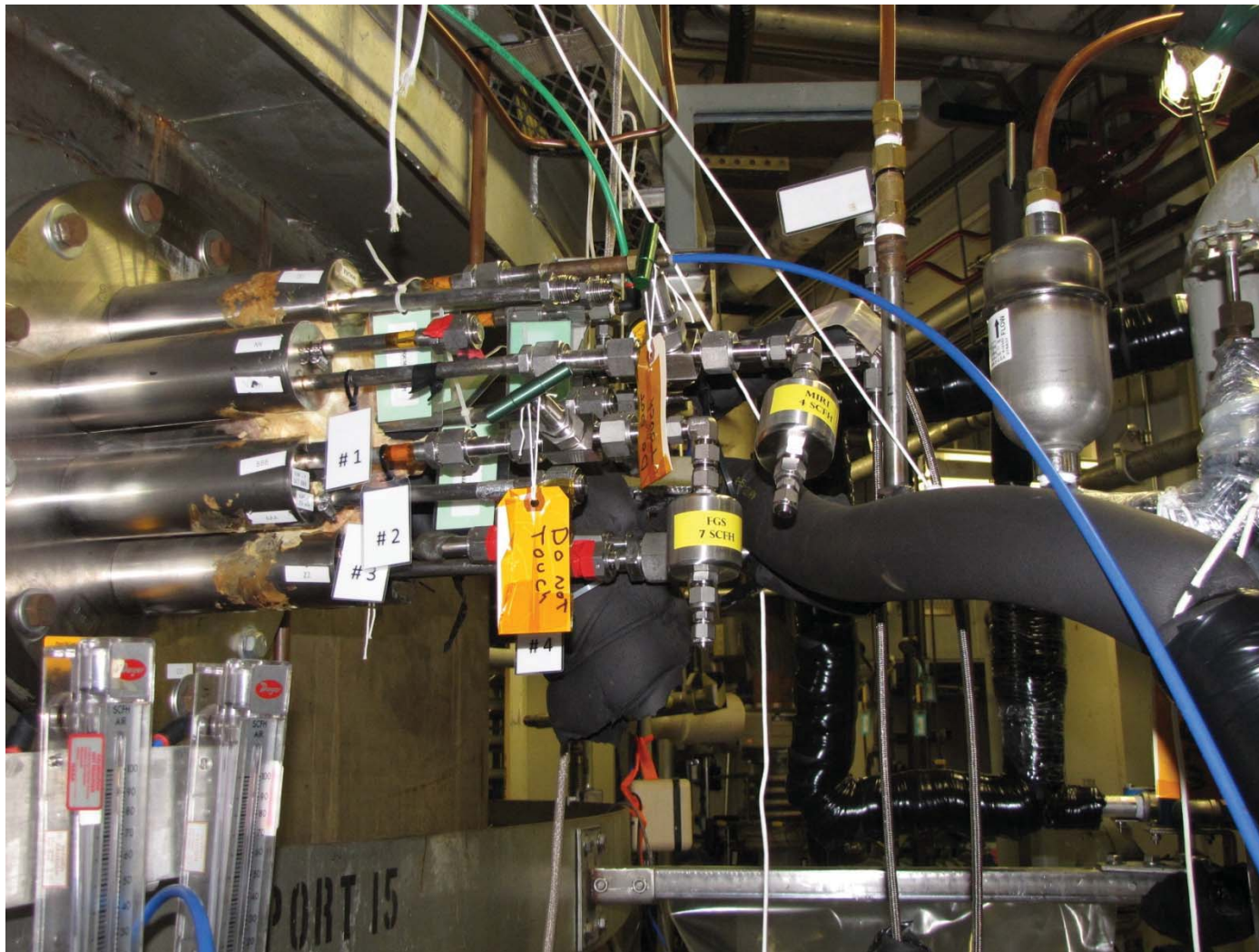


Power outages: Generators & UPS

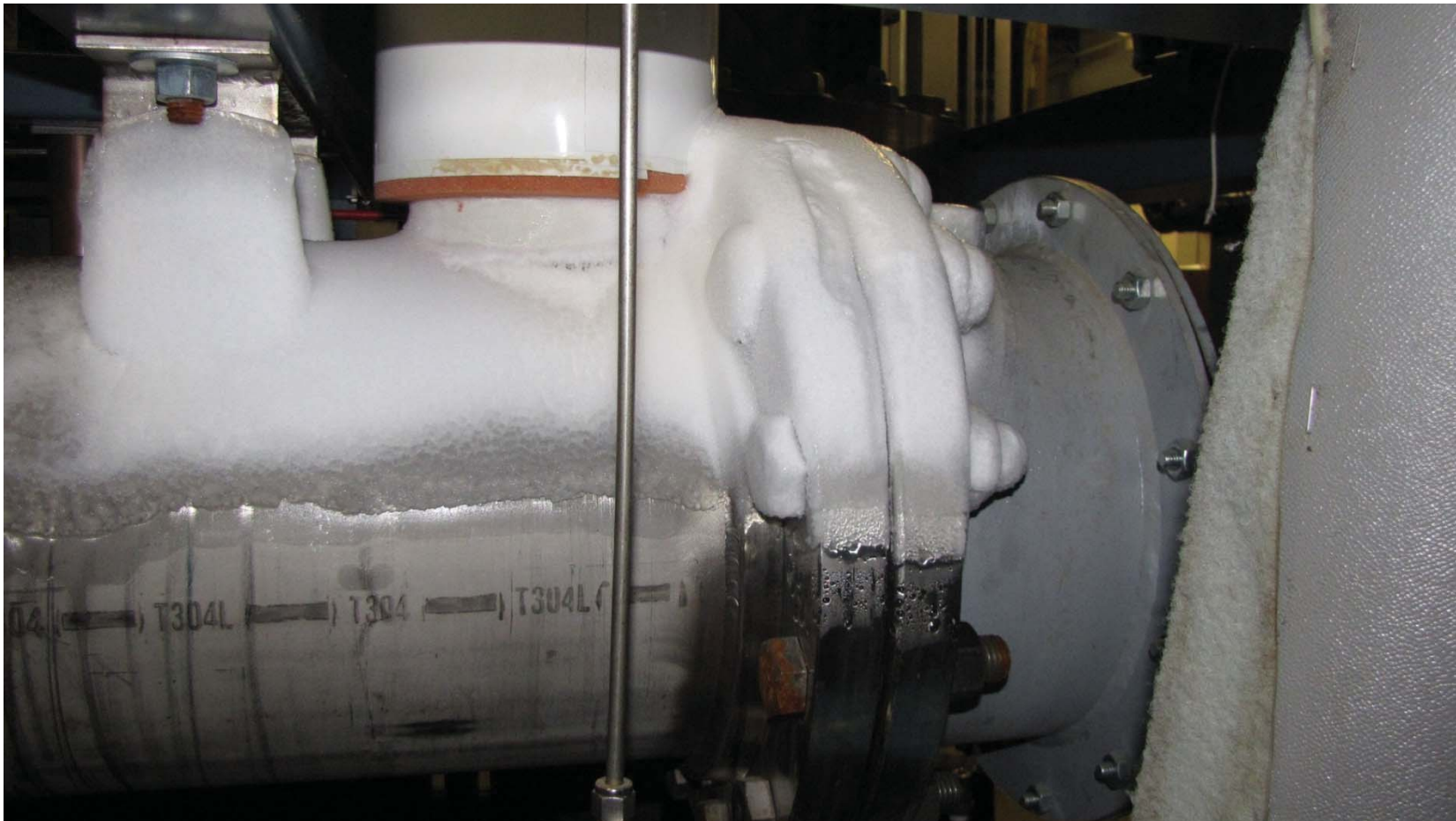
- # of power outages: 1
- Operated seamlessly. B10 generator & Helium skid UPS
- Short commercial power outage experienced on 09/21/2013 (approx. 21:43).
 - Several heater racks needed to be manually reset, but no significant impacts to test hardware.
 - He skid operation not impacted.
 - After coming back online, CQCM heaters came on full power and CQCMs achieved >350K.



MIRI Air Leak



Helium Skid Issues #5: LN₂ purifier needed to be cleaned
Warm up heater begins to leak when cold
Causes differential pressure to increase



Updated Predict

Steady State Predict Versus Measured

Thermal Load	Thermal Model Predict *	ISIM CV2 Measured (7/15/14 12:00PM UTC)	ISIM CV2 Measured (7/21/14 8:46AM UTC)	ISIM CV2 Measured (7/28/14 1:02PM UTC)	ISIM CV2 Measured (7/29/14 5:30PM UTC) **
MIRI Thermal Shield	9.5 mW \pm 2 mW	8.1 mW \pm 7.5 mW	7.2 mW \pm 7.5 mW	6.14 mW \pm 7.5 mW	5.26 mW \pm 7.5 mW
MIRI OM	17.6 mW \pm 6 mW	25.9 mW \pm 2.8 mW	30.6 mW \pm 2.8 mW	23.12 mW \pm 2.8 mW	19.27 mW \pm 2.8 mW
Boundary Conditions	Assumed Thermal Model (7/15/14 at 12:00PM UTC)	ISIM CV2 Measured	ISIM CV2 Measured	ISIM CV2 Measured	ISIM CV2 Measured
ISIM Conductive Temp at HSA feet (ISIM HKT-14)	35.91 K	35.91 K			34.74 K
ISIM Conductive Temp at MIRI feet (ISIM HKT-35/36/37)	32.79 K	32.79 K	Delta between 7/15 & 7/21 = 4.7 mW accounting for detector dissipation		Delta between 7/28 & 7/29 = 3.85 mW accounting for MIRI CQCM dissipation
ISIM Radiative Temp (STMS T ⁴ * Area Weighted Avg)	Used actual measured STMS panel temps and includes other actual instrument temperatures	34.65 K			
MIRI Shield Temp (Avg of Rails)	29.53 K	29.53 K			
MIRI OM Temp	6.31 K	6.31 K		6.2 K	6.27 K
MIRI Detectors	OFF	OFF	ON	OFF	OFF
MIRI CQCM	OFF	ON	ON	ON	OFF

* See presentation note field for details on changes in predicted loads.

** At equilibrium on MIRI OM load however this is not the officially declared steady state data point.

